

**MINERALIZATION OF BACTERIA IN TERRESTRIAL BASALTIC ENVIRONMENTS: COMPARISON WITH POSSIBLE LIFE FORMS IN MARTIAN METEORITE ALH84001.** K.L. Thomas-Keprta<sup>1</sup>, D. S. McKay<sup>2</sup>, S. J. Wentworth<sup>1</sup>, T. O. Stevens<sup>3</sup>, A. E. Taunton<sup>4</sup>, C. C. Allen<sup>1</sup>, E.K. Gibson Jr.<sup>5</sup>, and C.S. Romanek<sup>6</sup>; <sup>1</sup>Lockheed Martin, Mail Code C-23 NASA/JSC, Houston, TX 77058 (KThomas@EMS.JSC.NASA.GOV), <sup>2</sup>Mail Code SN, NASA/JSC, Houston TX 77058, <sup>3</sup>Battelle, Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352, <sup>4</sup>Dept. of Chemistry and Biochemistry, University of Arkansas, Fayetteville AR 72701, <sup>5</sup>Mail Code SN4, NASA/JSC Houston, TX 77058, <sup>6</sup>SREL, Drawer E University of Georgia, Aiken SC 29802

Microbial life on Earth exists in a wide variety of environments and profoundly affects the Earth's geochemical cycles [e.g. 1-3]. However, little is known about the taphonomy of microorganisms, particularly when features have been altered by diagenesis or mineralization [e.g. 4-6]. The identification of microfossils can contribute to the understanding of mineral resource formation [7], the history of life on Earth [e.g. 4], and whether specific features in meteorites and samples returned from space may have a biogenic origin [8]. Few studies have addressed the formation of biogenic features in igneous rock environments, which may be important to many of these phenomena, including the controversy over possible biogenic features in the basaltic martian meteorite ALH84001 [8]. To explore the formation of biogenic features in igneous rock environments, we examined microorganisms growing in basaltic microcosms. Microbial communities were harvested from aquifers of the Columbia River Basalt (CRB) group and grown in microcosm containing unweathered basalt chips and groundwater [technique described in 3]. These microcosms simulated natural growth conditions in the deep subsurface of the CRB, which should be a good terrestrial analog for any putative martian subsurface ecosystem that may have once included ALH84001 [9].

Inoculated, fresh (control), and sterile solution rock chips were examined with a high resolution Philips XL 40 field emission gun scanning electron microscope (FEGSEM) and a JEOL 2000 FX transmission electron microscope (TEM). FEGSEM samples were coated with ~2-5 nm of Au-Pd conductive coating. Uncoated microorganisms were also examined in the TEM at 160 kV.

We examined over 30 surfaces of rock chips from the inoculated basaltic microcosms. The chips displayed forms which we interpret as organisms and related features; similar shapes are present on TEM mounts. We observed three dominant morphological forms: Type 1: oval shaped (coccobacillus) form with a smooth surface texture which ranged from ~1-2.5  $\mu\text{m}$  in length and slightly less in width. Type 2: a similarly shaped coccobacillus form in the same size range but with a textured surface composed of thousands of thin (~2-5 nm diameter) interwoven filaments composed of ferrihydrite, an Fe+3 hydroxide (Fig 1). Type 1 and 2 organisms are significantly mineralized; both types of organisms appear hollow. It is not clear if the formation of a mineralized shell was a replacement for the original cell wall or a coating that developed external to the cell. Nevertheless, there was no evidence for the preservation of any ultrastructure, such as the cell wall (Fig 1). Type 3: tubular (bacillus or rod) forms to which a single appendage may be attached at one end. They range from ~0.30 -2.4  $\mu\text{m}$  in the longest direction without appendage. Micro-colonies of bacillus forms are frequently observed embedded by webby biofilm (Fig 2). Type 3 organisms are composed mainly of C, O, Na with minor P, S, Cl; they are unmineralized cells. In addition to the organisms, we observed attached and unattached filaments (Fig 3). Filaments are generally longer and thinner than organisms; they have distinctive tubular morphologies. Attached filaments are similar in composition to the Type 3 unmineralized cells. Unattached filaments are composed of ferrihydrite; their composition is similar to the Type 2 organisms. Some unattached filaments are hollow (Fig 3). We believe that these unattached filaments are mineralized cellular appendages. If so, it is clear that the mineralization of bacteria is not necessarily restricted to the main body of the organisms; much smaller appendages can also be preserved. The present observations suggest that microfossils in basaltic environments may contain little carbon, may lack evidence of cellular ultrastructure, and may include mineralized sub-cellular appendages. The presence of abundant biofilm may also serve as a substrate upon which minerals may be deposited. If so, it is likely that mineralized web-like biofilms may also be preserved and suggest previous biogenicity.

Recent work suggests that extraterrestrial features found in martian meteorite ALH84001 may be nanometer-sized fossils [8]. The ALH84001 features include small-sized filaments, fragments of filaments, possible cell morphologies, and possible biofilm [10]. The range of size and shapes of the biogenic features on the CRB microcosm chips overlaps with and is similar to those on ALH84001 chips (Figs 3-6). Although this present work does not provide evidence for the biogenicity of ALH84001 features, we believe that based on criteria of size, shape, and general morphology, a biogenic interpretation for the ALH84001 features remains plausible.

**References:** [1] Parkes R.J. et al. (1994) *Nature* **371**, 410 [2] Krumholz L.R. et al (1997) *Nature* **386**, 64. [3] Stevens T.O. and McKinley J.P. (1995) *Science* **270**, 450. [4] Hoffman H.J. and Schopf J.W. (1983) in *Earths Earliest Biosphere. Its Origin and Evolution*. (ed. J.W. Schopf, Princeton University Press) 321. [5] Mann H. and Fyfe W.S. (1989) *Can. J. Earth. Sci.* **26**, 2731. [6] Ferris F.G. et al. (1986) *Nature* **320**, 609. [7] Southam G. and Beveridge T.J. (1994) *Geochim. Cosmochim. Acta* **58**, 4527. [8] McKay D.S. et al (1996) *Science* **273**, 924. [9] Boston P.J. et al (1992) *Icarus* **95**, 300. [10] McKay D.S. et al (1997) *LPSC* 28, 919

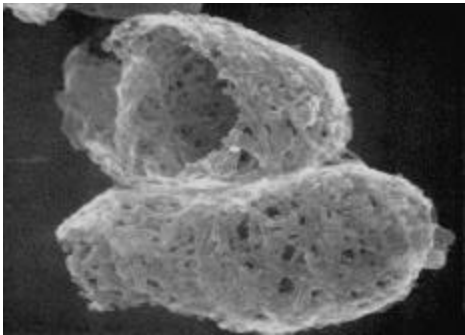


Fig 1. Mineralized Type 2 CRB organism; cell wall preservation is not apparent.

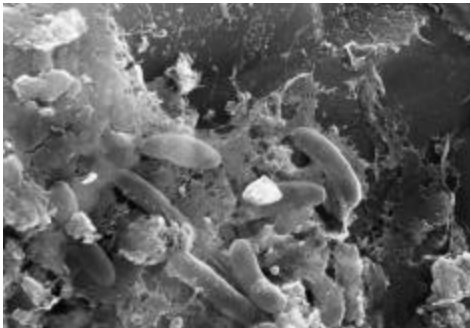


Fig 2. Colonies of Type 3 CRB organisms embedded in webby biofilm.

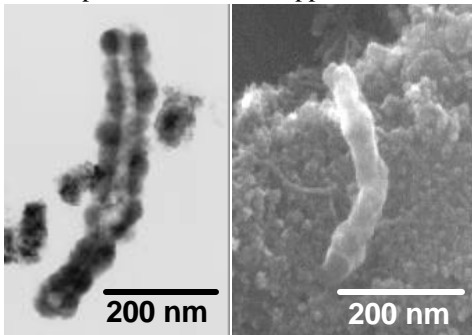


Fig 3. Unattached, mineralized, CRB filaments; hollow filament on left.

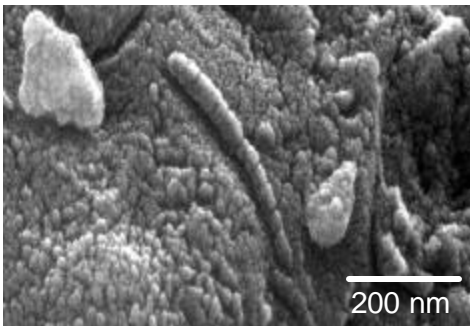


Fig 4. ALH84001 features suggested to have a possible biogenic origin.

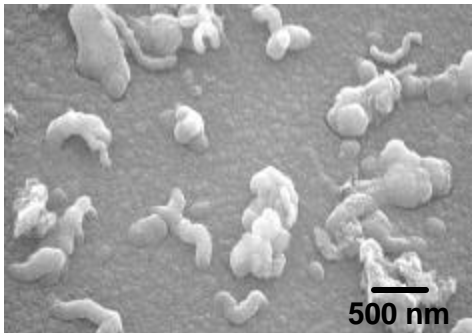


Fig 5. Mineralized CRB filaments on a basalt chip.

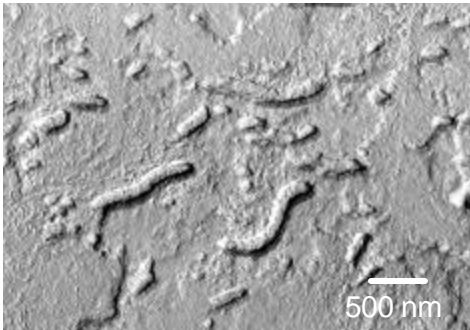


Fig 6. Possible biogenic features (filaments?) from uncoated surfaces of ALH84001 carbonate globules (Picture taken by H. Vali)